Section 19

EO-1 Spacecraft Bus Performance

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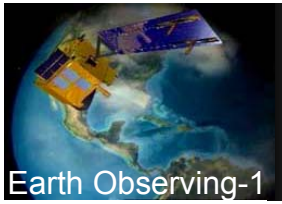


Overview of EO-1 On-Orbit Performance

Mission Technology Forum

- ***The EO-1 spacecraft, developed by Swales Aerospace, is "hugely successful"***
  - ***Nearly flawless during deployment, early orbit, and normal operations***
  - ***All subsystems meet or exceed performance requirements***
- ***Only one S/C anomaly in the ten months since mission launch***
  - ***Intermittent GPS drop-outs caused by a data-format, mitigated by simple table load***
- ***One area of disappointing performance***
  - ***AST loses track at ~60 degrees to sun rather than ~30 degrees: no effect on normal operations. Other LM Star Trackers show similar performance.***
- ***Many areas perform better than required and expected. These include***
  - ***ACS stability during images is better than the goal***
  - ***Supporting 8 to 10 images a day, more than twice the design requirements***
  - ***S-band uplink/downlink margin is more than 25 dB higher than budgeted***
- ***Command and ground station errors during early orbit checkout caused anomalous conditions during first week***
  - ***The S/C team recovered each incident quickly, without problems***
- ***Additional subsystem performance to follow***

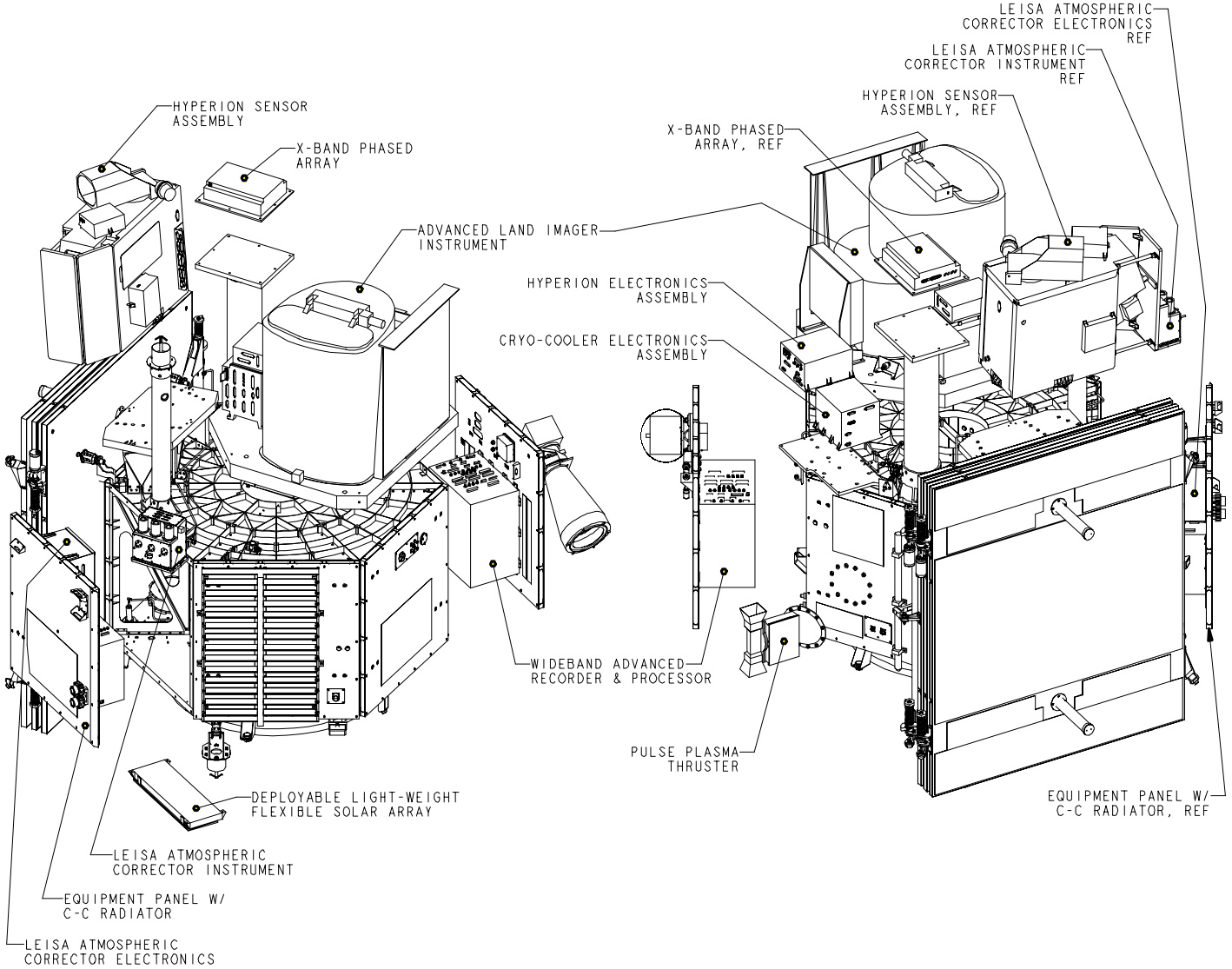
EO-1 Spacecraft Description

- ***Attitude Control***
  - ***Three-axis stabilized, with 3 RWA, 3 Torque-Bars, Autonomous Star Tracker (AST), Magnetometer, HRG Inertial Reference Unit***
  - ***Achieves pointing accuracy of <50 arcsec (3σ) in all three axes***
  - ***GPS for position and time***
  - ***Independent safehold processor***
  - ***Coarse Sun Sensors for safehold attitude reference***
- ***Power***
  - ***Deployable three panel solar array; >700W***
  - ***NiCd battery 50 Ahr, 28V $\pm$ 7***
- ***C&DH***
  - ***Mongoose V processor at 12 MHz; redundant PROMs***
  - ***Redundant 1773 fiber optic data bus***

EO-1 Spacecraft Description

- ***Propulsion***
  - ***22 kg Hydrazine used for orbit maintenance, formation flying, correcting insertion errors, and de-orbit***
  - ***Four thrusters at 0.2 lb each, canted for 3-axis control***
- ***Structure and Mechanisms***
  - ***Milled aluminum zenith and nadir decks, aluminum honeycomb equipment panels***
  - ***Supports satellite 588kg, designed for Delta II Dual Payload Attach Fitting (DPAF) loads***
  - ***HOP-actuated, redundant solar array release***
- ***Thermal***
  - ***Passive system. Heaters controlled by thermostats, radiators on outside of equipment panels sized to maintain 10 – 30°C***
  - ***Louvers on battery panel / radiator to conserve heater power***
- ***RF***
  - ***S-Band uplink (2 kb/s) and downlink (2 kb/s to 2 Mb/s), 2 omni antennas***
  - ***X-Band 105 Mb/s for science data***
  - ***Backup image-data path at 2 Mb/s using S-Band***

EO-1 Spacecraft Configuration

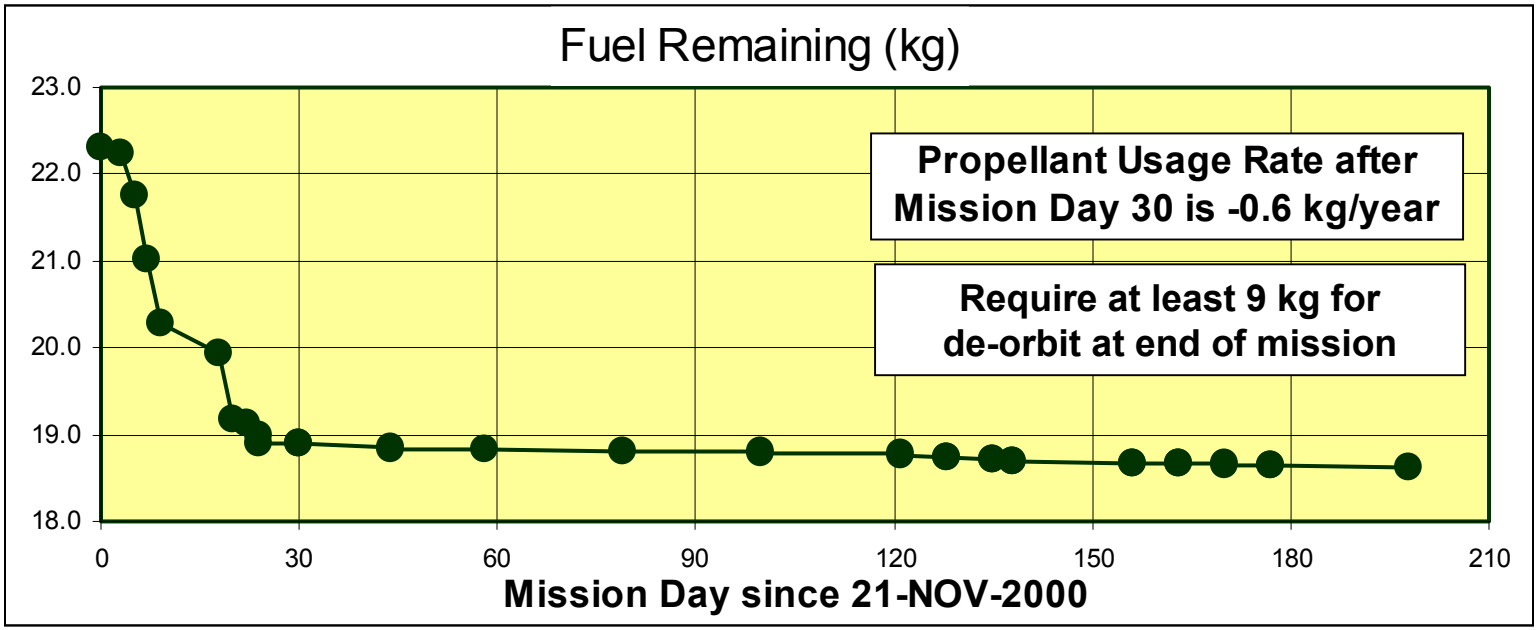


Attitude Control Subsystem Summary

- ***All of the attitude control functions continue to perform within requirements and in many cases with plenty of margin***
- ***Safehold Control was validated during the Early Orbit Checkout period and performance was flawless***
- ***Autonomous Star Tracker outages and SEUs have all either self-recovered or have been corrected by the AST Standby Mode TSM/RTS sequence***
- ***GPS Watchdog trips on the GPS Week rollover have occurred a few more times; a TSM/RTS sequence was developed to relieve FOT actions***
- ***Detailed analyses, simulations and procedures underway for PPT experiment***

	Requirement	*On-Orbit Performance*
Attitude Controller Errors	*[30, 30, 30] asec, 3σ*	*Consistently under 30 asec*
Attitude Knowledge	*[54, 108, 54] asec, 3σ*	*All axes consistently under 36 asec, 3σ during normal nadir-pointing operations*
Navigation Accuracy	*[130m Cross-Track, 100m Along Track] 3σ*	*Cross-track 45m, Along track 55m, Radial 30m, 3σ*
Jitter/Rate Stability		*Better than 0.5 asec/sec, 3σ during imaging*

Delta-V Maneuvers Summary Plots

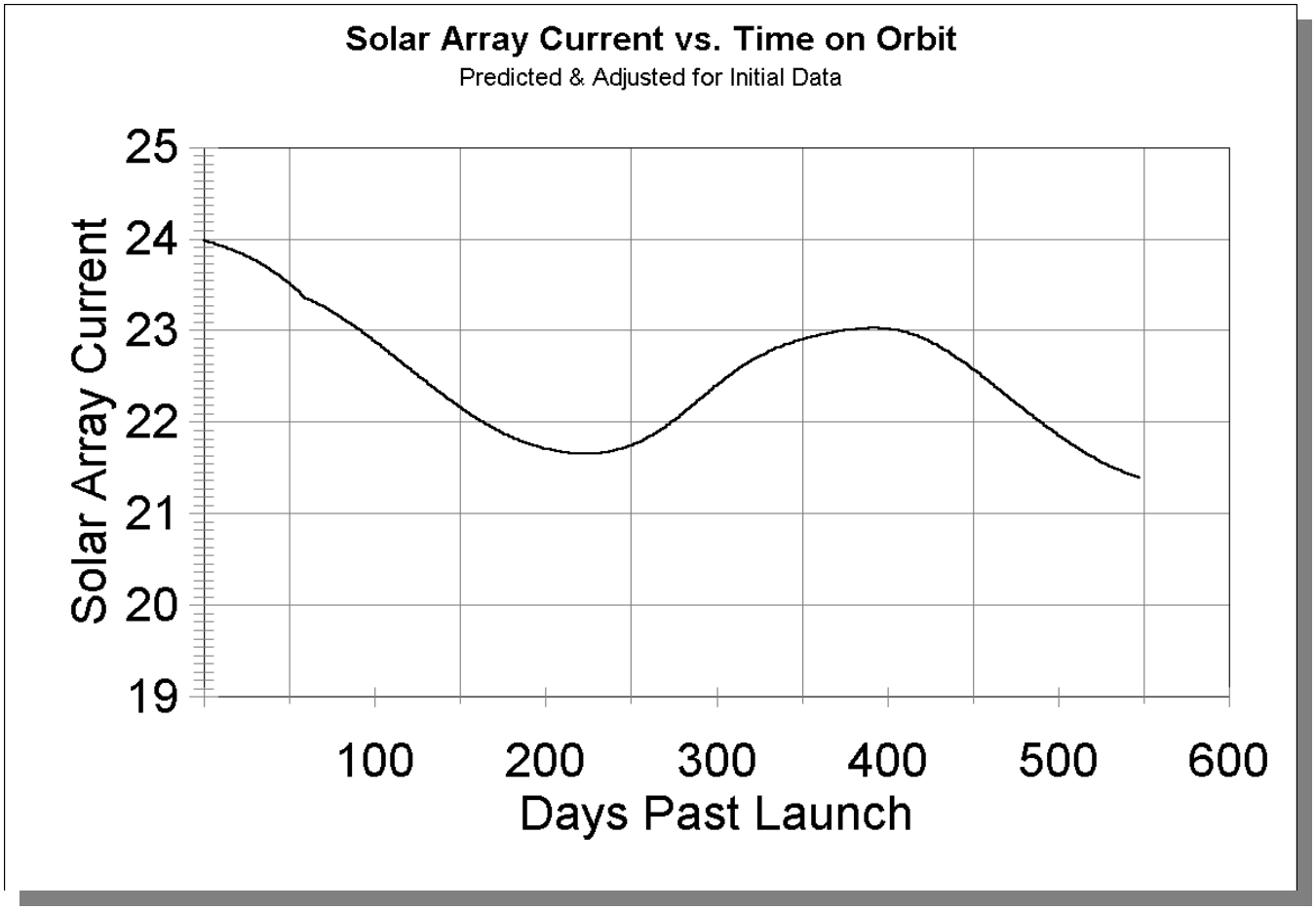


- ***Following completion of all mission objectives, all propellant will be expended to de-orbit EO-1***
  - ***Initial study using currently available fuel, indicates over 40 burns of 16 min duration due to blowdown curve***
  - ***Circular orbital altitude will be lowered from 705 to 590 km, with uncontrolled reentry in 10 years (required to re-enter in 25 years)***
- ***EO-1 carries enough fuel for 15 years of orbit-maintenance maneuvers prior to de-orbit***

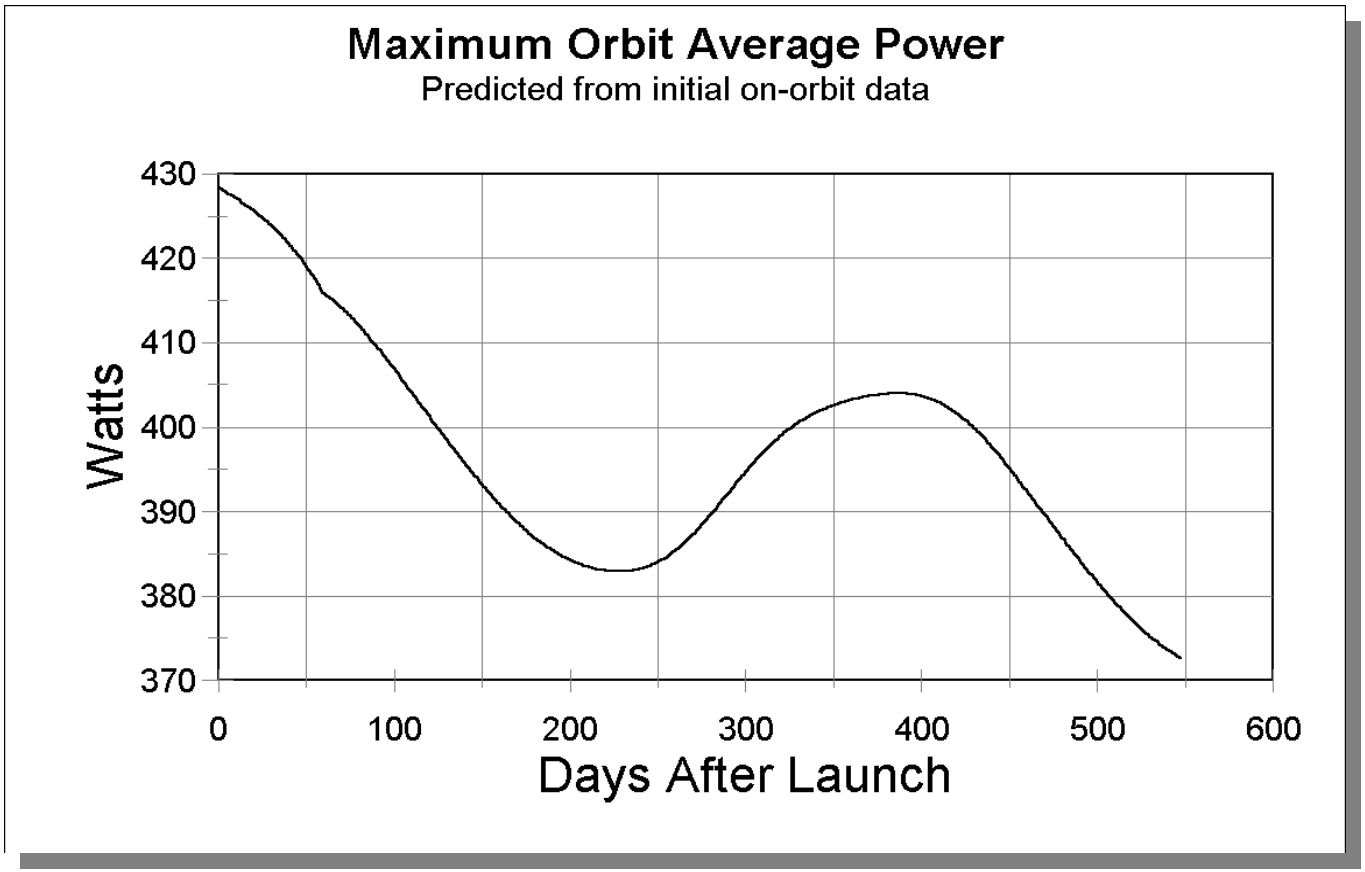
Power Subsystem Summary

- ***Solar Array max current ~22.3A (as of day 160) 0.6A above pre-launch model predictions***
  - ***Initial max current of 24A was higher than initial predictions***
  - ***Radiation (UV and Electron) degradation not as severe as predicted***
- ***Battery minimum voltage ~26.9V as of day 160***
  - ***Trend data shows expected, slight degradation in battery minimum voltage***
  - ***Estimated trend as -590 micro-volts per day***
  - ***At this rate, at least 5 years before low voltage causes a problem on orbit***
- ***Performance required to support Spacecraft***
  - ***Orbit average power required for high-activity orbit is ~330W***
  - ***Battery achieves 100% state of charge in ~33 minutes, trickle charge for remaining sunlit duration (>30 minutes)***
  - ***Updated model predicts >370W available at day 550. Since this is aphelion (solar intensity at minimum), an additional 180 days can be assumed (to mission day 730) as the solar intensity rises towards Perihelion***
  - ***Power system can support nominal operations beyond 2 years if existing trends continue. Power management of payloads can extend life of mission into years 4 and 5.***

Solar Array Prediction

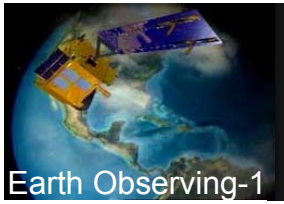


Orbit Average Power Predictions



RF Comm Summary

- ***No on-board anomalies***
  - ***All early-orbit anomalies have been explained by ground station or ground system problems or configuration issues.***
- ***No observed degradation in performance***
  - ***Both S-band and X-band have significant margin***
- ***2 Mb/s is now the standard downlink rate for housekeeping telemetry***
  - ***Eases operational burden compared to initial 1 Mb/s rate***
- ***The RF system should continue to operate without degradation in performance***



Command & Data Handling (C&DH) Summary

- ***No hardware anomalies***
  - ***Single bit errors observed, at expected rate, due to radiation; No effect on performance***
  - ***Small, expected drift in M5 oscillator is corrected automatically using GPS data***
- ***No 1773 unexplained bus errors or retries observed (EO-1 uses a redundant 1773 data bus for time distribution, commands, and telemetry)***
- ***No adverse effects seen when Enhanced Formation-Flying (EFF) stress the system by increasing CPU utilization to 100%***
- ***Software performing flawlessly***
- ***C&DH system should continue to operate for many years with no expected reduction in performance***

Thermal Subsystem Summary

- ***Launch Conditions Nominal***
  - ***Battery cooling with Fairing air performed as predicted***
- ***Post Ascent Nominal***
  - ***Less than 1°C rise in battery temperature***
- ***No Changes to Nominal Configuration Since Launch***
  - ***Adequate coverage of Thermistors, all temperatures within limits***
  - ***0 % Spacecraft Heater Duty Cycle***
  - ***Seasonal temperature variations observed, no degradation***
- ***Backside of Solar Array 10°C cooler than pre-launch predictions***
  - ***Release Rod Capture Canister Conduction Coupling was corrected and post-launch model predictions match flight predictions***
  - ***No adverse effect on Solar Array performance***
- ***No degradation in performance expected during the next year***

Software Summary

- ***All 15 Real-time Tasks (including ACS & EFF) in the C&DH main processor (Mongoose 5) have performed as designed***
- ***No event messages or restarts caused by either critical or non-critical tasks failing to reporting in to health and safety on a timely basis***
- ***No restarts have occurred in the main onboard computer or any of the other processors on the EO-1 S/C since launch***
- ***Attitude determination and control software has exceeded all performance criteria for guidance and navigation of the EO-1 S/C***
- ***Table loads have been used to load new TSMs for failure detection and correction and for optimizing the attitude control parameters of the EO-1 spacecraft***
- ***All single-bit errors have been corrected when detected in the DRAM memory and no multi-bit errors have been detected***

Summary

- ***The Swales Aerospace EO-1 Spacecraft Bus performance exceeds all requirements***
- ***The Spacecraft has operated flawlessly, with no processor resets, safehold entries, hardware anomalies, or unexplained events***
- ***At current performance both RCS and Power subsystem will extend life of mission well beyond 18 month requirement***